Effect of Brushing with Different Cleansing Solutions on Surface Roughness of Two Denture Base Materials

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Abstract

The most common cleansing method for removable denture is brushing. However, brushing causes the surface roughness of denture base. The degree of roughness could be affected and varied with the abrasive properties of cleansing agents. This study aimed to compare the abrasiveness of three different cleansing solutions distilled water, dentifrice (Colgate®), dishwashing liquid solutions (Sunlight®) on poly (methyl) methacrylate (PMMA; Vertex™) and a polyamide (Bioplast®). Forty-eight specimen blocks of PMMA and polyamide were prepared (n=24) and randomly assigned to the distilled water, dentifrice, and dishwashing liquid groups (n=8). The simulated brushing was performed by immersion specimen in the assigned cleansing solution and brushing using an automatic brushing machine. Surface roughness (SR) was measured using the average value of roughness (R_a) by the contact profilometer before and after 20k- and 40k-cycle of brushing. The differences of R_a among cleansing solutions were determined by the Kruskal-Wallis with Mann-Whitney U post hoc test. The pairwise comparisons between two time points were estimated by the Wilcoxon signed-rank test. Scanning electron microscope (SEM) was also used to observe surface topography. Mechanical cleansing by brushing with cleansing solutions caused an increase of SR in both PMMA and polyamide. In PMMA brushing with dentifrice resulted in the highest R_a after 20k- and 40k-cycle (0.230 µm and 2.411 µm, respectively), meanwhile dishwashing liquid caused the roughness comparable with distilled water. For polyamide, the R_a of dentifrice and dishwashing liquid groups after 40k-cycle were 0.109 µm and 0.139 µm which were significantly greater than brushing with water. In conclusion, mechanical cleansing with dentifrice caused the SR with the statistical significance in PMMA. On the contrary, SR caused by brushing on polyamide with dentifrice and dishwashing liquid were slightly increased but still below the acceptable threshold for oral biofilm retention after 40k-cycle. Dentures with the long-term brushing with dentifrice should be regularly monitored the surface morphology. Dishwashing liquid can be used as a reasonably alternative denture cleansing solution based on the simplicity, cost-effectiveness, and non-abrasive property.

Keywords: *Surface roughness/ Denture cleansing solution/ Denture hygiene/ Denture base*

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Introduction

Optimal denture cleansing is essential in maintaining oral and overall health among patients wearing dentures. Several dental problems, oral infections and systemic diseases, including gastrointestinal infection and pneumonia, may originate from colonized microorganisms on denture surfaces.[1-4] Cleansing of removable denture can be performed by mechanical, chemical, or combined methods. Various types of brush and chemical cleansing agents have been suggested.[5-7] Among several cleansing methods, conventional brushing is widely employed because of simplicity, cost-effectiveness, and efficacy in removing plaque and stain.[5,8]

Brushing may deteriorate surface texture of denture. It can initiate a surface roughness (SR) and loss of surface detail that impact denture adaptation and esthetic.[9-13] The SR increases biofilm accumulation, microbial colonization and discomfort of wearers. The oral biofilm is a complex aggregated community of bacteria, fungi and other microorganisms which relates to dental caries, periodontal disease and denture stomatitis. As reported by Bollen et al,[14,15] the average value of roughness (R_a) of 0.2 µm was the threshold value for bacteria retention. Several bacterial strains have been identified from the denture biofilm, such as *Streptococcus*, *Bacteroides*, *Fusobacterium*, *Veillonella*,

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Lactobacillus, *Prevotella,* and *Actinomyces.*[16] Occurred bacterial retention enhanced the fungal adhesion, and commensal living in the oral pathologic biofilm form.[17]

The magnitude of SR from brushing depends on several factors, particularly the abrasiveness property of cleansing agents.[13,18-22] According to the American College of Prosthodontists, the non-abrasive denture cleansers have been recommended as the cleansing agents of choice.[23.] From the economic constraint in developing countries, the regular agents for denture cleansing are water, dentifrice and dishwashing liquid/soap. However, the differences in SR from these agents have been insufficiently investigated. In addition, another common denture base material is polyamide. From flexibility and other properties, polyamide is usually used as the denture base material in some indications, such as alveolar ridge with undercut, atrophy alveolar ridge, allergy to poly (methyl methacrylate) (PMMA) material. The study on SR from mechanical cleansing on polyamide has been also limited. Therefore, this study aimed to determine the differences of SR caused by brushing with various types of cleansing solutions on each denture base material, including PMMA and polyamide. The null hypothesis was that there was no difference of R_a among the various cleansing solutions.

Materials and methods

Conventional heat-polymerized acrylic resin denture base material (PMMA, Vertex™ Rapid simplified, Vertex-Dental B.V., Zeist, Netherlands) and injection-mold thermoplastic denture base material (polyamide, Bioplast®, Denken-Highdental, Kyoto, Japan) were included in this study. Twenty four specimens of each material were prepared and allocated to 3 groups of cleansing solution (n=8); distilled water, dentifrice (Colgate® Cavity Protection, Colgate-Palmolive, Chonburi, Thailand) and dishwashing liquid solution (Sunlight® Lemon Turbo, Unilever, Bangkok, Thailand). Details of all material used were summarized in Table 1.

Specimen preparation

PMMA and polyamide specimens were made according to manufacturers' instruction. Each specimen was prepared and cut into a 8x8x4 mm block (Figure 1a). Then the blocks were centrally embedded in self-cured acrylic resin block (10x20x8 mm). Both PMMA and polyamide specimens were wet-polished by 800-grit, 1,000-grit, and 1,200-grit silicon carbide paper for 1 minute-each at 150 revolutions per minute (RPM) on automatic polishing machine[24] (Nano 2000, Pace Technologies, Tucson, AZ, USA). After polishing, the specimens were thoroughly rinsed with tap water to remove debris and dried with compressed air for 20 seconds. All specimens were stored in 37°C distilled water for 7 days before undergoing simulated brushing.

Table 1 Composition of Materials

Product (Composition)	Manufacturer	Composition	Processing Method
Denture base materials			
Vertex™	Vertex-Dental B.V. , Zeist, Netherlands	PMMA, MMA	Heat polymerization at 100°C for 20 mins in curing flask
Bioplast®	Denken-Highdental Co, Ltd., Kyoto, Japan	99% Aliphatic polyamide	Melting at 230°C for 15 mins and pressure injected at 0.7 MPa
Cleansing solutions			
Colgate® Cavity Protection	Colgate-Palmolive Ltd. Chonburi, Thailand	Dicalcium phosphate dihydrate, Aqua, Glycerin, Sodium lauryl sulfate, Cellulose gum, Sodium monofluorophophate, Tetrasodium pyrophosphate	
Sunlight® Lemon Turbo	Unilever Co, Ltd. Bangkok, Thailand	Alkylbenzene sulfonate, Sodium salt, Sodium lauryl sulfate	

Simulated brushing

Specimen blocks were securely mounted in an automatic brushing machine (V-8 Cross brushing Machine, SABRI Dental Enterprise, Inc., Villa park, IL, USA) (Figure 1b). A toothbrush with plane surface of 3 rows and soft rounded-end bristles (Gum Classic 311, Sunstar Americas, Inc., Chicago, IL, USA) was fixed to the holder and adjusted into contact the specimen with a load of 1.5 N (Figure 1c). Constant brushing of 55-mm range in back-and-forth motion was set with 100 strokes/min. The specimen and toothbrush were immersed in a container of cleansing solution (Figure 1d). Distilled water was selected as the control, compared with dentifrice and dishwashing liquid solutions . The dentifrice slurry was prepared by mixing 25 mg of dentifrice with 50 ml of distilled water. For dishwashing solution, 25 ml of concentrated dishwashing liquid was diluted with 50 ml of distilled water. All cleansing solutions were prepared by a mechanical homogenizer and were replaced every 10k-cycle of brushing strokes. Specimens were cleaned under running water, then the R_a was measured and later inspected by scanning electron microscope (SEM). The SR and SEM measurements were performed at baseline, after 20k-, and after 40k-cycle of brushing.

Surface roughness and SEM measurement

The R_a was determined using the contact profilometer (Talyscan 150, Taylor Hobson, England) equipped with the 2 µm tip radius of inductive gauge stylus. The tracing length was 2 mm at the tracing speed of 500 µm/sec and the cut-off length of 0.25 µm. Six parallel measurements, with each 400 µm apart, were performed in two perpendicular directions. The R_a was calculated as the average of the 12 measurements of each specimen. The SR measured area was captured with SEM (Quanta 250, FEI, Eindhoven, Netherlands) under low vacuum mode at an acceleration voltage of 10 kV and a magnification of 500x.

Statistical analysis

The differences of R_a among cleansing solutions at baseline (T0), after 20k-cycle (T20000) and after 40k-cycle (T40000) of brushing were determined by the Kruskal-Wallis with Mann-Whitney U post hoc test. The pairwise comparisons between two time points were analyzed using the Wilcoxon signed-rank test. The testing was determined separately according to material types. All statistical analyses were performed by SPSS software version 22.0. The statistical significance was considered when $p < 0.05$.

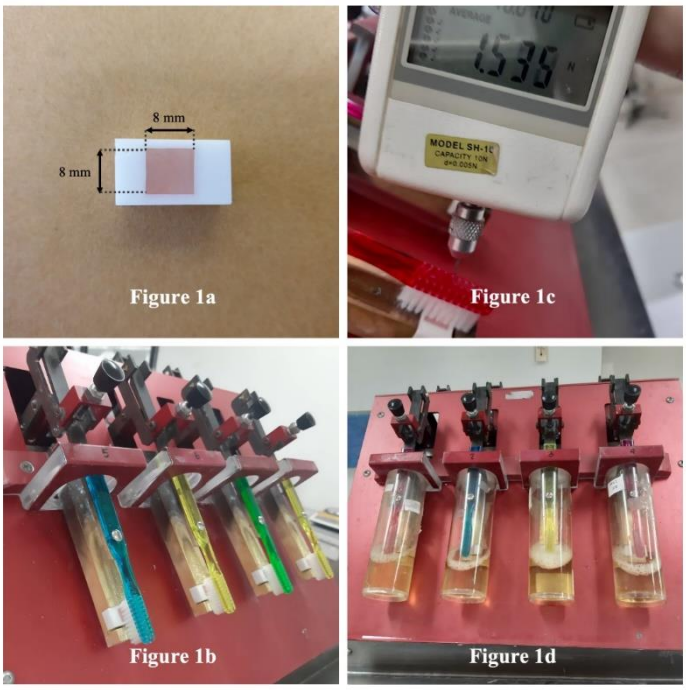

Figure 1 Specimen and simulated brushing (a) Specimen block; (b) Securely mounted in a toothbrush machine; (c) Contact load; (d) Immersion of cleansing solution

Results

Surface roughness of PMMA

The R_a at baseline and post-brushing were depicted in Figure 2. The pairwise comparisons of R_a showed the significant increase after 20k-cycle and 40k-cycle of brushing comparing with baseline in all groups. The changes of R_a seemed to be greater at 20k-cycle to 40k-cycle interval compared with baseline to 20k-cycle. Moreover, the proportion of increase were higher in dentifrice group. Meanwhile, the water and dishwashing liquid groups were comparable.

The median (minimum, maximum) of R_a in all groups were shown in Table 2. At baseline, R_a of all groups were approximate 0.09 µm without significant differences among groups. At 20k-cycle and 40k-cycle of brushing, the PMMA specimens in dentifrice group had the highest roughness with R_a of 0.230 µm, and 2.411 µm, respectively. On the contrary, the R_a of dishwashing liquid group was relatively comparable with the water at every time point.

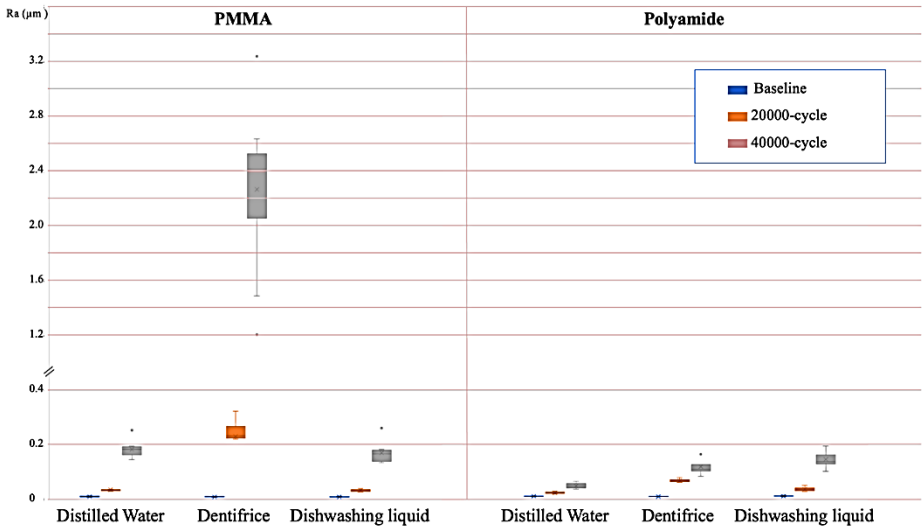

Figure 2 Changes of R_a

Table 2 Median of R_a

Cleansing solution	R_a (µm)*		
	T0	T20000	T40000
Material: PMMA			
Distilled Water	0.009 (0.008, 0.012)^{a,A}	0.034 (0.029, 0.051)^{b,A}	0.182 (0.144, 0.253)^{c,A}
Dentifrice	0.009 (0.007, 0.011)^{a,A}	0.230 (0.076, 0.322)^{b,B}	2.411 (1.203, 3.236)^{c,B}
Dishwashing liquid	0.009 (0.007, 0.011)^{a,A}	0.034 (0.026, 0.041)^{b,A}	0.166 (0.133, 0.260)^{c,A}
Material: Polyamide			
Distilled Water	0.011 (0.009, 0.013)^{a,A}	0.023 (0.019, 0.031)^{b,A}	0.044 (0.036, 0.065)^{c,A}
Dentifrice	0.010 (0.008, 0.014)^{a,A}	0.068 (0.053, 0.079)^{b,B}	0.109 (0.084, 0.168)^{c,B}
Dishwashing liquid	0.011 (0.008, 0.015)^{a,A}	0.035 (0.028, 0.050)^{b,C}	0.139 (0.102, 0.195)^{c,B}

* Median (Min, Max)

T0, baseline / T20000, after 20-k cycles / T40000, after 40-k cycles

The different superscript small letter indicates significant differences among cycle brushing stokes (T0; baseline, T20000; after 20-k cycles, T40000; after 40-k cycles) within the same cleansing solution ($p<0.05$). The different superscript capital letter indicates significant differences among cleansing solutions within the same cycle brushing stoke ($p<0.05$)

Surface roughness of polyamide

The R_a of polyamide also continuously increased after brushing with all cleansing solutions. At 20k-cycle of brushing, the SR was significantly different among all groups. R_a of distilled water, dentifrice, and dishwashing liquid group were 0.023 µm, 0.068 µm, and 0.035 µm, respectively. At 40k-cycle, specimens which were brushed with dentifrice and dishwashing liquid had the significant higher R_a compared with brushing by water. However, there was no significance between dentifrice and dishwashing liquid groups.

Scanning electron microscopy

SEM analyses were performed perpendicular to the surface of specimens. The highest and lowest amplitudes of SR were represented with the lightest and the darkest in grayscale. In PMMA specimens (Figure 3), the dentifrice group showed remarkably valleys representing the abrasive wear. The width of these valleys seemed wider in this group. For the polyamide material, brushing wear was less significantly displayed in SEM (Figure 4). Cleansing polyamide with dentifrice and dishwashing liquid showed higher roughness than water. Again, the wider abrasive valleys were observed in the dentifrice group.

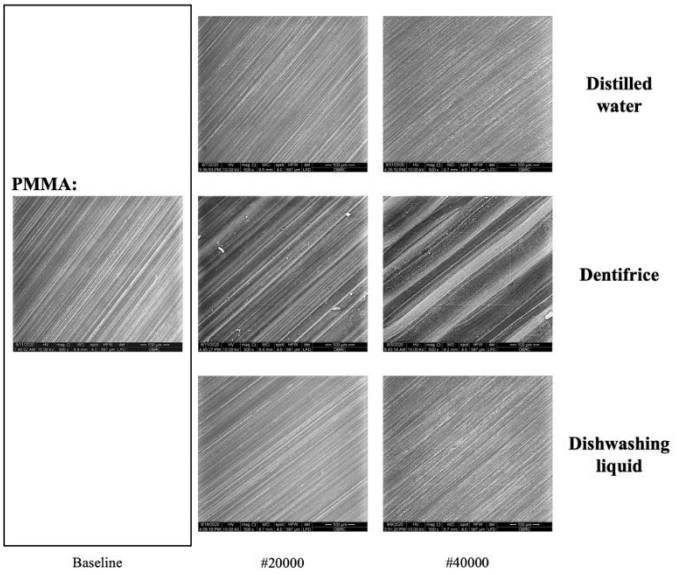

Figure 3 Scanning Electron Microscopy of PMMA (500x magnification)

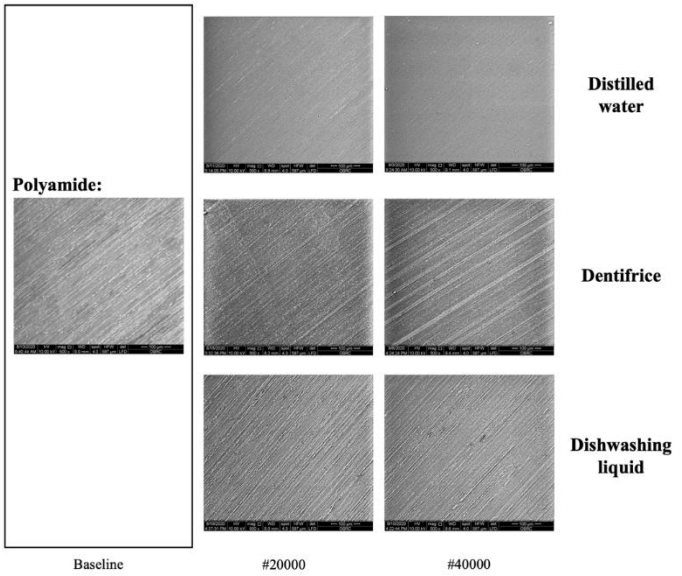

Figure 4 Scanning Electron Microscopy of Polyamide (500x magnification)

Discussion

Surface topography of denture base was clearly affected by mechanical cleansing. The result showed that the SR of PMMA and polyamide were significantly increased after simulated brushing with cleansing solutions, and the degree of roughness was varied with the cleansing solutions, therefore the null hypothesis was rejected. Cleansing solutions played an essential part on surface abrasion. Brushing with dentifrice caused the largest roughness in PMMA. It was concordant with the finding from previous studies that abrasive particles in a dentifrice were the main cause of these roughness.[9,10,18,20,22] The Colgate Cavity Protection was used as the representative of dentifrice because it has been widely used. This formula contains abrasive particles of dicalcium phosphate with the relative dentine abrasion (RDA) of 80. It was ranked as mild to moderate abrasive dentifrice according to the RDA value.[21] Harrison et al[19] suggested that the degree and characteristic of roughness depended on shape, size, and quantity of abrasive particles. Moreover, the roughness from dentifrice might also be mediated by the bristle hardness.[10] Small filaments or soft bristles brush may cause similar or even higher abrasion than the harder brush when brushed with dentifrice.[10,13] This was attributed to the soft bristles retained more abrasive particles within their narrow inter-filaments space and also provided higher contact area with the material.[10]

Dishwashing liquid and mild soap are recommended as the alternative cleansing solutions for removable dentures.[5,23] However, the evidence regarding abrasion of denture base from brushing with these solutions is very limited. Our results demonstrated that PMMA specimens brushed with dishwashing liquid solution had the level of abrasion approximate to the water. Similarly, in relining resin material, Izumida et al[11] showed the minimal SR from brushing with coconut soap. Less abrasion of dishwashing liquid and mild soap is due to the absence of abrasive particles. The active ingredient in soap/dishwashing liquid is a sodium lauryl sulphate (SLS), an anionic surfactant, which is effective in removing oily substances and polymeric matrices of biofilm.[25] Moreover, SLS also had a microbiocidal effect by solubilization of the microbial cell membrane and denaturation of its capsid proteins.[25,26] At this juncture, dishwashing liquid could be an alternative denture cleansing solution for PMMA denture base, which has the efficacy of cleansing, and caused less the mechanical wear.[8,27,28]

To select the proper denture base materials, PMMA and polyamide are used with different indications, thus the aim of this study was only to assess the SR form mechanical cleansing on both materials, not to compare between them. Interestingly, our results found that dentifrice and dishwashing liquid caused mild to moderate wear on the polyamide specimens, but this roughness was still less than the threshold of 0.2 μm at any time points. Polyamide has the surface hardness lower than PMMA but showed more resistance to brushing than PMMA in all cleansing solution. This result was in line with Chang et al[18] which reported that polyamide resin exhibited lower levels of brushing abrasion and weight loss compared with conventional heat polymerization, high impact, and CAD/CAM PMMA. The result of their study indicated the hypothesis that surface roughness was not only dependent on surface hardness, but water absorbability, elasticity and wear resistance were also influenced.[29-31] In our study all specimens were immersed in cleansing solutions during simulated brushing, the swollen surface of polyamide from higher level of water absorbability may reduce the amplitude of wear from the measurement of profilometer, then the SR was lower.

Various guidelines of removable denture cares have been proposed. Some suggested denture brushes and chemical denture cleansers are not available in developing countries.[5,6,8] The most common cleansing method is brushing with traditional toothbrush combined with dentifrice,[8,9,32] particularly patients with removable partial denture, because it is convenient for patients to use the same instruments for both their natural teeth and dentures. Although, our study showed that brushing with dentifrice

caused the significant roughness on denture surface, it could not be indicated that this protocol should be omitted. Roughness can be resolved by professional polishing in the recall visit. Twenty thousand strokes of simulated brushing would be equivalent to approximately 2 years of regular daily brushing.[33] Before reaching 0.2 μm threshold and causing prosthesis discoloration, discomfort to patients and contribute to microbial colonization and biofilm formation, patients wearing denture should be rechecked every 1-2 years. Denture cleansing methods, complaint of discomfort, denture morphology, and oral examination should be simultaneously considered during the recall visit. The roughness of the denture surface could be visibly detected or by asking the patients how they feel. Jones et al[34] showed that normally the patients were able to distinguish the surface roughness approximately at 0.5 μm. In this case, the professional polishing is recommended to maintain a proper denture surface. In addition, even absence of surface irregularity detected by visual inspection and patient perception, having the signs of mucositis and the history of long-term brushing with abrasive cleansing, denture adjustment including professional polishing is also suggested. Various clinical chairside polishing kit systems have been proposed and proved that some of those produced sufficiently smooth surface with roughness value well under 0.2 μm.[35]

This study also had some limitations. It was based on the laboratory -*in vitro*- setting, which might not perfectly duplicate a clinical situation. Simulated brushing motion was limited only back-and-forth direction, as well as a thermo-cycling was not used to replicate oral environment in thermal and humidity aspects. Secondly, the outcome focused only the SR detected by profilometer and SEM. Other important parameters including biofilm and stain removal efficacy, weight loss and surface gross, which also affected by the personnel denture cleansing, were not investigated. Finally, several factors, also affected the magnitude of surface abrasion, such as hardness of bristles, brushing force, number of brushing strokes, and concentration of cleansing solution. Variation of any factors mentioned earlier could deviate the degree of SR from our results.

The SR of PMMA were dramatically increased after simulated brushing with dentifrice. While dishwashing liquid was a more proper substitute cleansing solution which caused less brushing attrition. For polyamide material, dentifrice and dishwashing liquid caused mild surface wear within the clinically acceptable limit. The routine check-up and professional polishing every 1-2 years is recommended.

Conclusion

Within the limitation in this study, the following conclusions were drawn:

1. Mechanical cleansing by brushing caused the roughness on denture base material. The abrasiveness property of cleansing solution played as the essential factor on the degree of attrition.
2. In PMMA, brushing with dentifrice caused the highest SR with the clinical significance, meanwhile, the dishwashing liquid was comparable with water.
3. The SR of polyamide from brushing with dentifrice and dishwashing liquid were slightly increased but still below the acceptable threshold for oral biofilm retention (R_a = 0.2 μm).
4. Long-term used dentures that are usually brushed with dentifrice should be regularly monitored for any changes in surface morphology. While the dishwashing liquid can be used as an alternative denture cleansing solution based on the simplicity, cost-effectiveness, and non-abrasive property.

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พิริยา สุดสวัสดิ์ แมนสรวง อักษรนุกิจ** สุจิน ชุมประเสริฐ****

บทคัดย่อ

การทำความสะอาดฟันเทียมด้วยการแปรงเป็นวิธีที่ถูกเลือกใช้มากที่สุด อย่างไรก็ตามการขัดถูจากการแปรงก่อให้เกิดความหยาบผิวต่อฐานฟันเทียม ซึ่งเป็นผลจากคุณสมบัติการขัดของสารทำความสะอาดที่นำมาใช้ร่วมในการแปรง วัตถุประสงค์ของการศึกษานี้คือ เปรียบเทียบคุณสมบัติการขัดของสารทำความสะอาด 3 ชนิด ได้แก่ น้ำกลั่น ยาสีฟัน (คอลเกต) และน้ำยาล้างจาน (ซันไลค์) ต่อพอลิเมทิลเมทาคริเลตและพอลิเอไมด์ ทำการขึ้นรูปชิ้นตัวอย่างจากพอลิเมทิลเมทาคริเลต (เวอร์เทค) และพอลิเอไมด์ (ไบโอพลาส) อย่างละ 24 ชิ้นงาน แบ่งชิ้นงานออกเป็น 3 กลุ่มกลุ่มละ 8 ชิ้นตามสารทำความสะอาด ได้แก่ น้ำกลั่น ยาสีฟันและน้ำยาล้างจาน ทั้งหมดถูกแช่ในสารละลายที่ผสมสารทำความสะอาดและถูกแปรงผ่านเครื่องจำลองการแปรงอัตโนมัติ ความหยาบผิววัดจากค่าเฉลี่ยความหยาบ (R_a) โดยเครื่องโปรไฟโลมิเตอร์รูปแบบสัมผัสที่ก่อนการแปรงและหลังการแปรง 20,000 และ 40,000 รอบ ทำการทดสอบทางสถิติด้วยการทดสอบครัสคัล-วอลลิส ร่วมกับการทดสอบแมนน์-วิทท์นีย์ยู (Kruskal-Wallis with Mann-Whitney U post hoc test) ในการทดสอบความแตกต่างของค่าเฉลี่ยความหยาบระหว่างสารทำความสะอาด และใช้การทดสอบวิลค็อกสัน ซายด์-แรงค์ (Wilcoxon signed-rank test) ในการทดสอบความแตกต่างของค่าเฉลี่ยความหยาบระหว่างจุดเวลา ลักษณะการสึกของพื้นผิวถูกวิเคราะห์ผ่านกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด ผลการศึกษาพบว่าการแปรงร่วมกับสารทำความสะอาดก่อให้เกิดความหยาบผิวต่อทั้งพอลิเมทิลเมทาคริเลตและพอลิเอไมด์ การแปรงด้วยยาสีฟันในพอลิเมทิลเมทาคริเลตที่ 20,000 และ 40,000 รอบ มีค่าเฉลี่ยความหยาบสูงที่สุดคือ 0.230 ไมครอน และ 2.411 ไมครอน ตามลำดับ ในขณะที่น้ำยาล้างจานก่อให้เกิดความหยาบผิวใกล้เคียงกับน้ำกลั่น สำหรับพอลิเอไมด์การแปรงด้วยยาสีฟันและน้ำยาล้างจานที่ 40,000 รอบ ค่าเฉลี่ยความหยาบคือ 0.109 ไมครอน และ 0.139 ไมครอน ซึ่งทั้งสองกลุ่มมีค่าเฉลี่ยความหยาบสูงกว่าการแปรงด้วยน้ำกลั่นอย่างมีนัยสำคัญทางสถิติ ดังนั้นจากการศึกษาสรุปว่าการแปรงด้วยยาสีฟันในพอลิเมทิลเมทาคริเลตก่อให้เกิดความหยาบผิวอย่างมีนัยสำคัญทางคลินิก ในทางตรงกันข้าม พอลิเอไมด์เมื่อแปรงด้วยยาสีฟันและน้ำยาล้างจาน ความหยาบผิวเพิ่มขึ้นเล็กน้อยแต่ยังคงอยู่ในระดับต่ำกว่าค่าเกณฑ์ที่ยอมรับได้ในการยึดเกาะของคราบไบโอฟิล์มหลังจากการแปรงที่ 40,000 รอบ ฟันเทียมที่ใช้วิธีการทำความสะอาดโดยการแปรงร่วมกับยาสีฟันเป็นเวลานาน ควรมีการตรวจประเมินสภาพพื้นผิวอย่างสม่ำเสมอ ในขณะที่น้ำยาล้างจานเป็นอีกหนึ่งทางเลือกของสารทำความสะอาดที่มีความเหมาะสม เนื่องจากใช้งานได้ง่าย ค่าใช้จ่ายไม่สูงและการไม่มีคุณสมบัติในการขัดสี

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